UNITED STATES MARINE CORPS
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STUDENT HANDOUT

INSTALL INTERIOR ELECTRICAL SYSTEMS

LEARNING OBJECTIVES:

a. Terminal Learning Objective:

(1) Provided a structure, construction blueprints, all schedules for circuits and materials, a selection of electrical materials, required tools and references, install an interior electrical wiring system such that the structure is wired per the construction blueprints and the installation is completed safely and on time per the references. (1141.03.06)

b. Enabling Learning Objectives:

(1) Provided electrical blueprints, studded cubical with pre-drilled studs and rafters, a breaker box with circuit breakers, conductors, hardware, and tools, install the breaker box in accordance with the National Electric Code (1141.03.06a).

(2) Provided electrical blueprints, a studded cubical with pre-drilled studs and rafters, a breaker box installed with circuit breakers, conductors, hardware, a selection of electrical components, and electrical tools, install the branch circuits such that the system reflects the electrical blueprints and is in accordance with the National Electric Code (1141.03.06b).

BODY

1. Installing the Breaker Box:

a. When installing the electrical system we will first cover the installation of the breaker box or better known as the panel box. The first step is to perform an inventory on all materials for the system installation. We want to identify all materials and match them against the Service Material Schedule.

b. The second step will be to study the electrical blueprints and determine the following:

(1) Location of installation.

(2) Type of service being installed.

(3) Inventory of tools required for the installation.

(4) Materials match the type of service installation to be performed.

(5) Clearances that must be maintained for the service mast and service entrance conductors. Vertical clearances can be found in Article 230-24 of the NEC.

c. There are two basic styles of services. A service fed from an overhead drop and a service fed from an underground service lateral. There are different variations of installing the two types of services. We will discuss four common ways of installing a service.

(1) Service Mast installed through roof using a flashing.

(a) The first step for installing the service mast through the roof and ceiling is to verify the exact location where the panel box will be installed.

(b) Select the point of entry for the service mast based on where the breaker box is intended to be installed and install the box . Use a level to ensure the box is square. If the ceiling is already installed you may want to wait to change the steps of installing around as we will cover shortly.

1 Measure the distance from the back of the breaker box to the center of the knockout that you intend on using for connecting the service mast. This measurement should be considered along with any possible obstructions that may hinder the service mast from being installed vertically straight.

2 Mounting of brackets or straps for support should also be considered. Think about how will this impact on the measurements already taken.

3 Using a level with a magnetic strip (level that magnetically adheres to ferromagnetic materials), hold the service mast in the intended path of installation. The service mast should be over the knockout of the panel box and the level should read vertically straight completely around. Pencil around the mouth of the service mast; thus, a circle should be left behind that indicates where you will drill.

4 If clearance of the service mast cannot be made due to the ceiling already being installed you can use a string with a weight called a plumb line. This weight should be symmetrical so that when the center of the weight is hung by a string directly over the knockout of the breaker box, the string is vertically straight above. You should mark a spot on the ceiling where the

string is using a pencil. You should then draw a circle that matches the diameter of the pipe ensuring that the mark from the string is directly in the center. You can use the string and weight to mark the roof also by ensuring the weight is hung directly over the center of the hole while marking the spot where the string is on the roof. This all takes place in the overhead crawl space or attic. You can also slide the service mast though the hole in the ceiling and using a level to ensure it is vertically straight mark the roof with a pencil by once again tracing the mouth of the service mast. Whatever method is used, it is important that the mast is installed plumb with the knockout of the panel box and that a method of supporting and securing the mast can occur.

5 To seal the exit of the service mast and to prevent water from entering through the roof a device called a flashing is used. The flashing is made using a treated piece of sheet metal or similar material some are also made of plastic. It also has a doom or cup like construction that lifts away from the base of the flashing where there is a hole is pre-drilled or cut. Around this pre-made hole is a rubber like seal. The flashing upward edge is slid under roofing shingles so that rainwater can flow down off the shingles, across the sheet metal and down the rest of the roof. Once the service mast is pushed up through the hole of the flashing the rubber like seal allows the transfer of the pipe from indoors to outdoors without the elements causing a problem.

(2) Service Mast using an Ell is another method of installing the service. This method is used when the mast is secured to the outside wall of the structure and a device called an ell makes a 90 degree bend that goes right through the wall. The entrance ell has a cover that aids in the efforts of pulling the service entrance conductors through the component. The ell comes with fitting that allows the service mast to be securely attached. The hole in the wall around the ell is sealed up. You can use a silicone-based caulking or a putty like material called duct seal.

(3) Service mast through overhang is another common method of installing the service mast. Going through an overhang normally requires both the use of a flashing and an ell.

(4) A service lateral installation is when the service is feed from underground. Often a pole is installed near the structure that requires electrical power. A mast with a weather-head is attached to the pole and continues below grade. Then, conductors that are ran through the mast travel to the structure where they enter by way of more conduit that connects to the panel box. The conductors enter and exit the conduits using a bushing.

(a) Conductors used for service laterals must be approved for underground use. The NEC covers these types of conductors and cables for direct burial. Article 230-30 and article 338 covers types U.S.E. (underground service entrance) and U.F. (under ground feeder) cables. 300-5 (f) also covers back filling

(b) Table 300-5 addresses the Minimum Cover Requirements, cables caring 0 to 600 Volts. These service entrance cables normally must be buried at lease 18 inches below grade. 300-5 (d) also states that “Service laterals that are not encased in concrete and that are buried 18 in. (457 mm) or more below grade shall have their location identified by a warning ribbon that is placed in the trench at least 12 in. (305 mm) above the underground installation.” Finally, as mentioned before, the service entrance cables are protected from physical damage by enclosing in conduit them when entering and exiting the earth (grade).

d. Other components that are common to all services are and how they are used are:

(1) The threaded end of the service mast is inserted into the knock out of the distribution panel (breaker box).

(2) Lock-nut (type of threaded washer services as a nut) is threaded onto the threaded end of the rigid conduit (service mast). One nut goes on the mast prior to it going through the knock out. A second lock nut is placed on the threaded conduit from the inside of the breaker box. The two lock nuts sandwich the panel box and secure the service mast.

(3) A bushing is threaded onto the service mast to protect the outer covering of the service entrance cables. Some installations may require the use of a bonding bushing. A bonding bushing is like a regular bushing except that it has a strap attached to it to bond the raceway to the grounding block of the panel.

(4) An overhead service drop must have a weather head (also may be called a “goose-neck”) attached to the top. These are procured separately and come in the sizes required to match the size of the conduit of the service mast. The cover has knockouts that must be punched to pull the cable through. Each conductor is intended to go through a separate hole. Weather heads may crack if they are tightened down to much when installing them on the mouth of the service mast. Some weather heads have threaded holes and are for use with rigid conduit. Others have clamping sleeves and are for use with other types of raceways.

(5) Most service installations will also require a meter base. This box has a front socket opening and is installed in line between the point where the service entrance conductors start and the panel. The utility company utilizes this base to plug in their meter so that they can measure total power consumed. The installation of the base is the responsibility of the electrician installing the service. Most meter bases are installed outside of a structure and also require the installation of a watertight hub at the point where the service conduit enters the meter base.

e. Article 250 gives all the requirements for grounding. Sometimes the grounding electrode conductor must be passed through the wall of the structure to be attached to the grounding electrode,

(1) The grounding conductor is connected to the neutral terminal or bar. The neutral/grounding bar at the main panel must be connected to the housing of the panel using a bonding strap or screw. This is referred to as the "Main Bonding Jumper". You will have to check the literature that the manufacture supplies and study the box to determine the best method of bonding. The neutrals and equipment grounding conductors should not be connected to the same bar inside sub panels. This should only be done at the main panel that feeds the sub panel.

(2) Table 250-66 covers sizing of the conductors for grounding. Match the conductor that came with the bill of materials with the table to ensure you have the correct size.

(3) The grounding conductor is connected to an approved ground. Article 250-62 covers all the approved materials. Article 250-64 "a" through "e" provides the requirements for Grounding Electrode Conductor Installation.

f. The circuit breakers or fuses for each circuit may be placed inside the panel box as each branch circuit is completed or in an order that prevents the lease confusion for the Marine doing the installation. Ensure that the directory of circuits is permanently marked at the time of installation to indicate the purpose of each circuit in accordance with article 110-22 of the NEC.

(1) Article 384-15 states not more than forty-two over-current protection devices shall be installed in any one cabinet or cutout box (breaker box or otherwise known as panel box).

(2) Ensure that you study the bus connections for 240 volt circuits and that double-pole breakers are installed for those circuits.

2. <u>Installing Branch Circuits</u>

a. Before you install any components for the branch circuits you should inventory the electrical components just as we did before installing the service equipment. Check the components against the following:

(1) Branch circuit schedule.

(2) Branch circuit Material schedule.

(3) Lighting Fixture Schedule.

b. Next you must determine what methods will be used to install the branch circuits.

(1) Conduit is required in all commercial installations and is likely to be required in most projects. There are many different types of conduit on the market and as technology improves

new types are invented. The type you select will most likely be determined by the type of structure, type of equipment served and location of the circuit(s) to be installed. If there is a question on which type to use consult the NEC or contact the local building inspector. We will discuss the types that are most often used.

(a) Rigid conduit comes in two main types:

1 PVC or nonmetallic conduit is joined together by couplings or fittings using a glue that is a solvent that welds the PVC secure. Article 347 covers Rigid Nonmetallic Conduit. This conduit can be bent using a thermal device that heats the pipe and allows it to be altered (commonly called a “heating blanket” or a “PVC heat box”. Using pre-made bends of different degrees is a common practice. This conduit comes in sizes from ½” to 6” in diameter

2 Metallic conduit requires threaded fittings. It is a very strong installation that provides maximum protection for conductors. Article 346 covers Rigid Metal Conduit. This conduit comes in sizes from ½” to 6” in diameter and is permitted to be used as an equipment grounding conductor. This conduit is very hard to bend and in most cases requires the use of a hydraulic bender.

(b) Intermediate Conduit is similar to rigid conduit, but the walls of the conduit are not as thick. Article 345 covers Intermediate Metal Conduit. This conduit comes in sizes from ½” to 4” in diameter and is permitted to be used as an equipment grounding conductor.

(c) Electrical Metallic Conduit (EMT) is probably the most common to use for installing branch circuits. This conduit is easy to bend and is usually done so with a hand bender. Article 348 covers Electrical Metallic tubing. This conduit comes in sizes from ½” to 4” in diameter. The most common sizes are 1/2” and 3/4”. EMT is joined together using special fittings that utilize pressure or a setscrew.

(d) Conduit normally comes in 10’ lengths. When ordering you should round to the nearest 10 and add 10 percent to the total.

(e) Except for the flexible conduit, the code does not allow more than four, 90 degrees bends or the angles made in any one run should not be more then the sum of those equal to four, 90 degree turns.

(f) Flexible conduit is becoming more popular but cannot be used for all situations. It’s usually used on runs that have many or difficult bends. There are many different types of flexible conduit. It comes in metallic and nonmetallic or a combination of them both. It comes with or without conductors that are preinstalled from the manufacturer. It normally comes in sizes from ½” to 4” in diameter and is packaged in a coil from 10 to 200

feet. You must research the lengths and uses of the different types of flexible conduit and select the best one for your installation.

(g) The NEC also requires conduit to be supported. This is normally done with conduit straps. Conduit straps are selected based on the type and trade size of the conduit that you are installing. They normally have one or two mounting holes. It is important to know what type of material that the conduit will be secured to (wood, concrete, drywall etc..) so that the proper fastening device (screw, anchor, toggle bolt etc..) is used. You will be required to research the type of conduit that you are installing.

(2) The method of installing conduit varies. You must consider the following:

(a) Surface mounted conduit is when the branch circuit is installed outside the wall. This installation requires the wall surface to be installed first.

(b) Installed inside the wall. When installing conduit in the walls you must consider:

1 Vertical runs of conduit. This is done by running conduit from junction boxes that are mounted on the top plate of the wall straight up and down. This requires drilling holes through the top plate. Likewise, a larger hole then the outside of the diameter is need through the first wood member so that the fitting that secures the conduit to the box will not be obstructed when the box is secured flush to the top plate of the wall.

2 Horizontal runs of conduit may require notches to be made through the wooden studs. This should method may weaken studs and should be used on large studs only.

(c) Article 300-4 allows certain conduits to be ran without metal plates protecting them.

(d) Cutting conduit is usually done with a hacksaw however, some types may require special cutting tools. It is important to ream the cut ends of conduit to remove rough edges so the insulation of the conductors is not damaged as they pass through the openings. This can be done with lineman’s pliers or reaming tools.

(e) Most conduit fittings and couplings can be installed by using screwdrivers and or adjustable pliers however special tools may be required.

(f) Bending conduit is an art and takes lots of practice. The most common types of bends are:

1 90 degree bend

2 45 degree bend

3 Offset bend

4 Saddle-back bend

(3) Using Nonmetallic Sheathed Cable (Romex) is another method that may be used to install branch circuits. Article 336 covers Nonmetallic Sheathed Cable.

(a) Just as if you were using conduit, when installing circuits using romex, after studying the electrical blue prints is to rough in the boxes. Boxes should always be installed before running conductors. Also you may be required to perform some carpentry to install the cable. If you're not sure of something, check with your NCOIC before cutting or drilling.

(b) Outlet boxes are either surfaced mounted or installed in the wall. This should be identified in the planing stage and verified during inventory. Follow the electrical blue prints for determining the placement of each outlet.

(c) Outlet boxes should be installed to the height specified in the plans. The code does not restrict the height or mandate the height of boxes. Generally, in a room most boxes are placed the same height. The length of a claw hammer is often used as a measuring gauge since they are readily available and can provide a fast and uniform method of determining height for all outlet boxes.

(d) Switch boxes for lighting are usually placed at heights from 46 to 52 inches. Once again the height placement of switch boxes is not mandated by the NEC. The installer should take into account the placement of switches as they relate to the way doors open. Switches should not be placed behind doors. They should serve the user without having to hunt behind objects.

(e) Ceiling boxes are located usually in the center of a room. When there are more then one light fixture in a room the room is normally divided into equal sections. Light fixtures are then placed center of each section to provide the best use of the lighting fixtures. Finding the center of a room or section can be done several ways:

(1) Running a string from corner to corner diagonally is one method. Where the two strings cross should be where the center is. This can be used if there are more then one light fixture by dividing the room up into equal sections and running the strings from the corners of each section.

(2) For installing rows of lights the center of the room or sections can be found by measuring with a tape measurer. Lights should be spaced so that lighting is uniform between rows. You can determine section for rows by dividing the room by length.

(f) Sometimes blue prints show only a rough path that conductors will take. The line that is drawn from component to

component may only show what is connected on what circuit. You may have to draft your own detailed plan. This may aid you especially if the system is busy. Whether your using conduit or nonmetallic sheathed cable, drafting a sketch for each room may save time. You can do a rough sketch that will show the number of conductors going to and from devices and boxes. Pictorial drawings are very useful for those Marines that have limited experience in wiring electrical systems.

(g) When installing nonmetallic-sheathed cable, it is important that bends in the circuit not damage the cable. Article 336-16 of the NEC states, "Bends in cable shall be made so, and other handling shall be such, that the cable will not be damaged and the radius of the curve of the inner edge of any bend shall not be less than five times the diameter of the cable"

(h) Article 336-18 of the NEC covers supports for nonmetallic sheathed cable. The NEC states, "Nonmetallic-sheathed cable shall be secured by staples, cable ties, straps, or similar fittings designed and installed so as not to damage the cable. Cable shall be secured in place at intervals not exceeding 4½ ft (1.37 m) and within 12 in. (305 mm) from every cabinet, box, or fitting. Flat cables shall not be stapled on edge. Cables run through holes in wood or metal joists, rafters, or studs shall be considered to be supported and secured".

(i) Cable must be protected from physical damage Article 300-4 (a) (1) and of the NEC covers cables and raceways through wood members and the text reads, "Bored Holes. In both exposed and concealed locations, where a cable or raceway-type wiring method is installed through bored holes in joists, rafters, or wood members, holes shall be bored so that the edge of the hole is not less than 1/4 in. (31.8 mm) from the nearest edge of the wood member. Where this distance cannot be maintained, the cable or raceway shall be protected from penetration by screws or nails by a steel plate or bushing, at least 1/16 in. (1.59 mm) thick, and of appropriate length and width installed to cover the area of the wiring".

c. Installing a circuit into a permanent structure is much different than hanging a wiring harness in a tent. You should always take your time, follow all the NEC codes that apply to the installation, follow all manufactures instructions, and ensure that the job is done right. Article 110-12 states "Electrical equipment shall be installed in a neat and workmanlike manner".

REFERENCES: NATIONAL ELECTRICAL CODE
WIRING SKILLS UNIT 1